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(54) **Devices for imaging written information**

(57) An image processing apparatus functioning as a writing device that images information as it is written on to a surface by measuring the forces applied at the stylus tip. The imaging device includes a ink pen cartridge and strain gauges mounted on a sensor that mechanically couples to the pen cartridge. The strain gauges measure lateral forces deflecting the pen cartridge, and the longitudinal forces pressing the cartridge into the pen housing. Alternatively, strain gauges can also determine the force of the pen tip against the writing surface. The gauges generate signals representative of the forces applied to the pen point as the pen moves along or presses against a writing surface. A further set of sensors can be employed to determine movement and orientation of the device relative to the surface even when the pen is not in contact with the surface. Data representative of the written images are captured by analyzing the forces applied to the pen point.

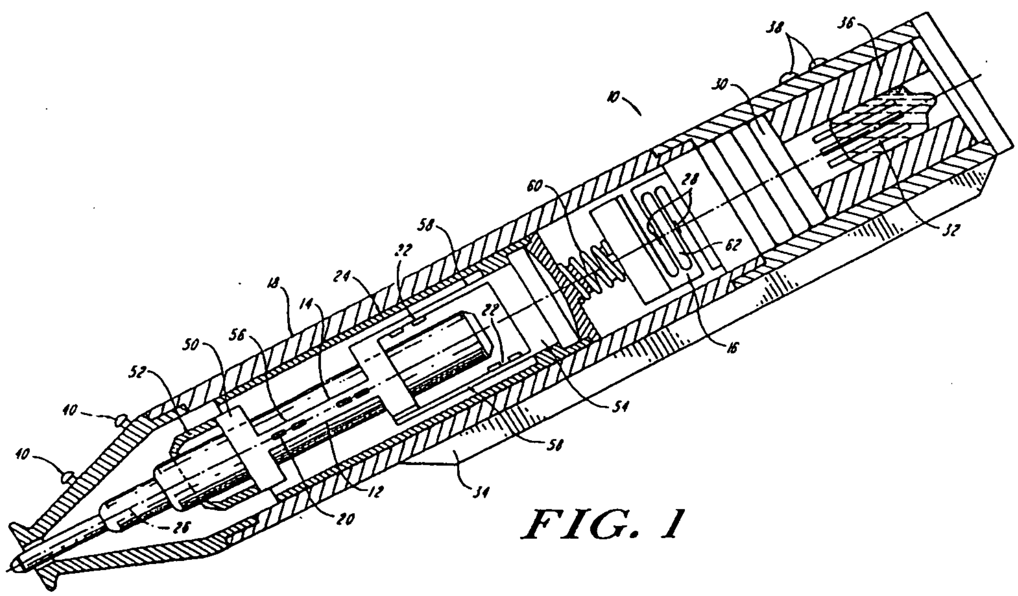

FIG. 1

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Description

The present invention relates to devices for imaging written information.

Various systems have been proposed in the past for capturing image information as the being traced information is written. Such systems typically detect forces that describe the pattern being traced out on a surface. These forces can be used to recreate the written image. How accurately written images can be recreated depends on how completely the forces describe the motion of the device against the surface. For example, forces acting on more than one axis of a pen point may represent that the pen point is moving along a writing surface, or may represent that the pen is being held at an angle on a stationary point. Without more information an accurate image cannot be obtained. The ability to image written information, therefore, is limited by the information concerning pen position and orientation.

For a device to image information accurately as it is written, data concerning the device's position on the writing surface, orientation to the writing surface and movement along the writing surface must be gathered.

In general, these devices gather information concerting movement by detecting the mechanical forces at the device's point while the point is in contact with the writing surface. To gather accurate information, imaging devices have typically employed special pen point cartridges for sensing mechanical forces. In many cases these pen point housings exhibit nonlinear behavior, i. e. elastic compression, thereby corrupting the sensed data. Furthermore, these housings are costly and too fragile for a typical work environment.

To process correctly the forces sensed at a pen point, the orientation of the device to the surface must be known. For example, the device's ability to distinguish between forces caused by the pen point being held at an angle at a stationary spot and forces caused by the pen point being moved along a surface, cannot be resolved unless the orientation of the device is known. Devices for imaging written information have typically required that the pen point be held at a specific angle, usually perpendicular to the writing surface. While this method allows accurate assessment of the forces when the pen point is held corrertly, its accuracy falls off with slight variations of orientation and is therefore often impractical for the ordinary work environment.

Another consideration for imaging written information is the need to accurately position new images relative to prior images. Once a pen has been lifted from a writing surface its position relative to its prior location on the writing surface is unknown. Devices for imaging written information have typically required a special surface capable of detecting a pen point. While this method gathers pen point position data, it burdens the use of imaging devices and at the same time substantially increases cost. To this end systems such as those disclosed in EPO 649 549 B1, have been developed that include sufficient sensors to allow for imaging information written on a conventional surface such as a sheet of paper. These sensors can be complex and expensive to manufacture. However, the use of these sensors provides devices with excellent performance and greater applicability.

It is, therefore, an object of the invention to provide an imaging apparatus having sensors that are more robust and less expensive to manufacture.

The invention relates to sensors for detecting forces acting on a stylus being employed to draw, write, create, trace or otherwise create an image of written information. Image processing devices for imaging written information are known in which a pen cartridge, a movement sensing means and a contact sensing means cooperate to determine the forces applied to the tip of the pen cartridge as the pen cartridge writes information on a surface. A tilt sensor element can be mounted to the housing for measuring the orientation of the pen relative to a writing surface.

Through the use of a pen cartridge, movement sensor and contact sensor, accurate information concerting the motion of the pen point can be obtained from devices held at natural angles. By determining forces along the longitudinal axis of the pen cartridge, forces indicative of pen motion can be distinguished from forces indicative of pen contact at a point on a surface. Because the device can be held at typical writing angles, there is no need for specially manufactured pen cartridges that maintain a known orientation from the surface.

To measure forces acting the pen, the invention provides a sensor for measuring an applied force that comprises a substrate having an upper surface, a lower surface, a peripheral portion, and a plurality of cutouts disposed between the upper and lower surfaces and spaced inwardly from the peripheral to form a deflecting portion disposed inward from the cutouts, and to form a plurality of arms that connect between the deflecting portion and the peripheral portion. In one embodiment the plurality of cutouts includes four cutouts and four arms. Further, the arms extend readily outward from the deflecting portion of the sensor and extend relative to a set of transverse axes. In an alternative embodiment, there are three cutouts and three arms of the sensor.

The sensors can further include transducers that are mounted to the plurality of arms to generate deflection signals representative of the deflection of the deflecting portion responsive to an implied force acting on the deflecting portion. Typically, the transducers are strain gauges, but can be any type of transducers suitable for generating a signal that is representative of the deflection of the deflection portion.

In a further embodiment, the sensors further include a circuit that electrically connects to the transducers for generating responsive to the deflection signal a force signal representative of the applied force. In an optional embodiment, the sensors also include a temperature compensator circuit for detecting a temperature charac-

teristic. The temperature compensator can couple to the circuit for directing the circuit to generate the force signal responsive to the temperature characteristic. In this way, a temperature compensator is employed to compensate for strains measured by transducers and caused by thermal expansion or contraction of the substrate body.

The substrate typically includes a silicon substrate or a metallic substrate. In the case of a metallic substrate, preferably, there is a ceramic coating on one of the surfaces of the substrate which typically is aluminum oxide.

In a further aspect, the invention can be understood as processes for manufacturing a sensor for measuring an applied force. These processes can comprise the steps of providing a substrate body having a peripheral portion, an upper surface and a lower surface, and forming within the substrate body, a plurality of cutouts that extend between the upper and lower surfaces and that are spaced inwardly from the peripheral portion to form a deflecting portion and a plurality of arms that connect between the deflecting portion and the peripheral portion. In a preferred embodiment of the invention, these processes include the step of milling a silicon wafer in order to provide the substrate body. The step of milline, can include the step of directing a laser beam at the silicon wafer, or directing an ion beam at the silicon wafer, or any other milling step suitable for cutting a substrate body from a silicon or metallic wafer.

Processes according to the invention can also include the step of milling the substrate material to have a select pattern for the peripheral portion. Accordingly, processes according to the invention can form sensors that have irregular geometrys to provide sensors that more easily fit within the housing of a pen assembly, or any other type of assembly.

The invention will next be described in connection with certain illustrated embodiments. However, it should be clear that various additions, subtractions and modifications can be made without departing from the spirit or scope of the invention. For example, although the invention is principally described in connection with pens and markers, any writing instrument or, more generally, any imaging or drafting device can employ the teachings of the present invention to capture image information. Moreover, the invention can be used not only with traditional writing surfaces such as pads of paper but any surface where frictional forces can be measured including, for example, blackboards, computer monitor screens and other visual display media.

Embodiments of the invention will now be described by way of example, with reference to the following drawings:

FIG. 1 is a schematic representation of an electronic imaging apparatus constructed in accordance with the present invention;

FIG. 1A is a more detailed illustration of a stylus for use in the apparatus of FIG.1;

FIG. 1B is a more detailed illustration of an inner housing component of a movement sensing means for use in the apparatus of FIG 1;

FIG. 1C is a more detailed illustration of a contact sensor for use in the apparatus of FIG. 1;

FIG. 2 is a view of the present invention disposed relative to a writing surface;

FIG. 3 is a schematic representation of an alternative embodiment of the present invention having a telescoping member; and

FIG. 4 is a schematic representation of an alternative embodiment of the present invention having transducers mounted to the stylus element.

FIG. 5 is a schematic representation of a further alternative embodiment of the present invention having transducer mounted on the outer face of the sensor element.

FIG. 6 is a schematic representation of the sensor element.

FIG. 7 is a schematic representative of the sensor that illustrates in more detail this location of the transducer elements.

FIG. 8A and 8B are schematic representations of alternative sensors.

FIG. 9A and 9B are further alternative sensors.

FIG. 10 schematically illustrates a stylus element mounted with a sensor as depicted in FIGs. 8A, 8B, 9A and 9B; and

FIG. 11 schematically illustrates a sensor assembly for connecting into a pen housing.

In FIG. 1, a system 10, is shown, including a stylus element 12, a movement sensor 14 and a contact sensor 16, all of which are disposed within a housing 18. Through the use of these subunits, signals are generated that represent the three dimensional forces describing the movement of a stylus tip as it traces a pattern on a surface. The invention provides sensors that can be employed within imaging devices of this kind. For clarity, the operation of such imaging devices will first be described.

As depicted in FIG. 1, the horizontal and vertical force sensing capability of the movement sensor 14 and the longitudinal force sensing capability of the contact sensor 16, combine to create a description of the forces acting on the tip of stylus element 12. In the embodiment shown, the stylus element 12, movement sensor 14 and contact sensor 16 are aligned in housing 18. The stylus element 12 is seated within the movement sensor 14, having its distal end extending from the housing means 18, and the contact sensor 16 is disposed rearward and separate from where the movement sensor 14 is connected to the housing 18.

The distal tip of the stylus element 12 can make contact with a writing surface for tracing patterns such as writing numerals or geometric figures. As the tip of the stylus 12 is moved across the writing surface to trace

this figure, the stylus element 12 behaves like a moment arm. FIG. 1A provides another view of a stylus element 12 separated from the rest of the system 10. As shown in FIG. 1A, the stylus 12 includes a tip 11, an ink reservoir 15 and a flexible nib 13 for transporting ink from reservoir 15 to tip 11. The stylus element 12 transmits the horizontal and vertical forces acting on the tip of the stylus clement 12 to the points where the movement sensor 14 connect to the housing 18. The flexible nib 13 of FIGS. 1 and 1A, serves to decouple the ink cartridge 15 from the movement sensor. The movement sensor 14 bends and deflects according to the moment resulting from the forces on the stylus tip. For the embodiment shown in FIG. 1, two pairs of transducers 20 and 22 generate signals proportional to the deflection of the movement sensor 14.

The embodiment depicted in FIG. 1, has the movement means 14 seated within an axially slidable inner housing 24. In this way, as the stylus element 12 presses against the writing surface, the movement sensor 14 slides along the longitudinal axis 26 of the stylus element 12 and axially compresses the contact sensor 16 in proportion to the force acting along the longitudinal axis 26. Transducers 28, mounted to the contact sensor 16 generate signals proportional to the force compressing the contact sensor 16.

As further shown in the embodiment of the invention depicted in FIG. 1, a power source 30, such as a battery, is placed rearward of the contact sensor 16. The power source 30 supplies power to the transducer eiements and to the tilt switch 32 and computer interface 36. The tilt switch sensor 32 is connected rearward of the power source 30.

The tilt sensor 32 illustrated in FIG. 1, is of a type known in the art for determining the angle of orientation from a level plane. In FIG. 1 the tilt sensor 32 is aligned along, or parallel with, the longitudinal axis 16. The orientation of the stylus element 12 to the writing surface is monitored while patterns are traced on the writing surface. The tilt sensor 32 produces signals indicative of orientation from a level plane by using a conductive electrolyte fluid surrounding a plurality of electrical conductors. The conductive fluid maintains a constant level within sensor 32. As the angles between longitudinal axis 26 and the surface changes, the conductive paths between the electrical contacts changes. The different electric paths formed indicate different angles of orientation between the writing surface and the stylus element 12.

The outer surface of the outer housing 18 include an asymmetric surface such as the ridge 34 shown in FIG. 1 to prevent the user from twirling the device 10 in his or her hand during usage. Similarly the inner and outer housing, 24 and 18, should be linked by a sliding grove or the like to prevent rotation of one vis-a-vis the other.

Additionally, in the embodiment of FIG. 1 an infrared or similar wireless data link establishes a communication path to an external processor, such as a microcomputer, for processing of the image signals representative of the patterns traced on the writing surface. As further illustrated in FIG. 1, one or more activation switches 40 can be disposed at the forward end of the outer housing 18, to generate control signals representative of information concerning the operating status of the system 10.

In use the device 10 is employed in conjunction with a data processing unit 64, as shown schematically in FIG. 2 to provide a facsimile reconstruction of the written information. The data processing unit can process the image signals through a bitmap algorithm. Bitmap algorithms, known in the art of facsimile reproduction, map points on the writing surface to points on a reference surface. Position information within the image signals can be translated by a mapping table on to the reference surface. Bitmapping provides scalable reconstruction of the written images and maps the image signals into the coordinate system of the absolute reference coordinate system. In a further embodiment, the processing unit processes the image signals with an algorithm that uses strokes of the stylus. The algorithm measures the time and rate of stylus tip acceleration and recreates electronic images of the written information. In yet a further embodiment, the processor unit processes the image signals through a spline algorithm as known in the art.

In one embodiment of the invention, a Wheatstone bridge having strain gauge reistors in the current paths is constructed so that the magnitude of the mechanical strain acting on the gauges makes a corresponding change in the electrical resistance of the strain gauge. It should be appreciated that similar transducer mechanisms well known in the art, such as Hall effect transducers, piezoelectric transducers or optical attenuation sensors, that similarly function to transform the mechanical forces into electrical signals, can be used in the present invention.

FIG. 1 illustrates one embodiment of a movement sensor 22 constructed in accord with the invention. The illustrated embodiment is a rigid support frame 50 constructed and dimensioned for axially receiving stylus element 12. This sensor is shown and described in EPO 649 549 B1. Similarly, FIG. 1 depicts one embodiment of a contact sensor which is also described in the above cited European Patent Publication.

As shown in FIG. 2, during the coordination of the different two reference systems, the stylus is disposed at a natural orientation for writing. The stylus presses against the writing surface with a force indicative of writing. The longitudinal sensor determines the resultant force transmitted along the longitudinal axis 26. The resultant force vector yields the angle θ between the writing surface and the stylus.

The longitudinal force is resolved into forces perpendicular to the writing surface, forces along, the horizontal axis and forces along the vertical axis of the writing surface. The horizontal and vertical component forc-

es resulting from the angular orientation of the stylus pressing against the writing surface are removed from the forces detected by the movement sensor.

The invention can image printed text, in part, because the position of one printed letter is maintained relative to the second printed letter. The user applies sufficient pressure against the writing surface to compress spring 60 and distort the contact sensor 16 while writing the first letter. After writing the first letter, the user stops exerting force against the writing surface and the spring 60 slides the inner housing 24 to the writing surface to maintain contact. As the stylus 12 is moved across the surface to the position for the second printed letter, the movement sensor 14 detects the horizontal and vertical forces and discerns the position of the second letter relative to the first. In this way, the signal generated by the contact sensor 16 encodes information concerning the printed image that allows a se s signal to be venerated which is an accurate representation of the printed image.

The relative position of traced images can be determined even when the device 10 is lifted from the writing surface. In essence, the stylus and/or inner housing forms a moment arm from which one can measure the forces of acceleration as the device 10 is moved above the writing surface by measuring the relative motion of the arm. The sensors and/or auxiliary sensors can then measure accelerations and calculate the new location of the device when it is subsequently returned to the surface. The acceleration forces can be processed according to known navigation functions and algorithms to determine the position of the stylus tip relative to the writing surface.

FIG. 3 illustrates an alternative embodiment of the present invention. As depicted in FIG. 3 the device 88 has a stylus element 90 that is axially slid inside a contact sensor 92. The rear-ward end of the contact sensor 92 is fixed to the housing 94. A movement sensor 96 is axially disposed over the forward tip of the stylus element 90 and a spring 98 is positioned between the movement sensor and abutment 100 of the stylus element 90.

The movement sensor 96 and stylus element 90 act as a moment arm for transmitting forces to the rearward end of the contact sensor. The contact sensor has a seat 102 for receiving the stylus element 90. The seat is connected to a transducer beam 104, extending rearward to the end connection with the housing. Two pairs of transducer elements 106 are mounted to each side of the transducer beam 104 and axially aligned with the longitudinal axis 108. Longitudinal forces acting on the contact sensing means 92 distort the transducer beam and alter an electrical property of the transducer element in relation to the distortion of the beam 104.

The telescoping movement sensor 96 axially slides along the longitudinal axis 108 to maintain contact with the writing surface when insufficient force is applied to the longitudinal axis to indicate writing. The movement sensor 96 has two orthogonally disposed transducer beams 110 extending to the forward end of the stylus element 90. Two pairs of transducer elements are mounted to each side of the transducer beams. The orthogonal displacement resolves the forces acting on the movement sensor into two independent component forces.

Figures 4 and 5 illustrate alternative embodiments of the invention. FIGs. 4 is discussed in EPO 649 549 B1. Figure 5 also illustrates an alternative embodiment of the present invention as discussed in EPO 659 549 B1. As depicted in FIG. 5, the device 250 has a stylus element 200 that is axially slid through an inertial mass 210 through a movement sensor 204 and into a seat element 202. In the illustrated embodiment, the seat 202 is a hollow, metallic cylinder that connects to the inertial mass 210, and extends rearwardly through the sensor 204. In one embodiment of the invention seat 202 is surrounded by a fexible circuit board. The movement sensor of this embodiment has a forward portion 226 and a rearward portion 228. The device 250 has a threaded positioning ferrule 215 that screws into the inertial mass 210. Activation switches 222 are disposed at the forward end of the device 250.

A tilt sensor 211 is positioned axially rearward of the seat 202 and connects, at its rearward end, to a power supply element 214. The power supply 214 is formed from a first forward cylinder 217, that is sized to axially slide into the tilt sensor 212 and form a rear-ward cylinder 219. Tilt sensor 212 connects as its forwarded end to seat 202 and to the housing 224 so that the rearward portion of the tilt sensor 212 and the connected power supply 14 form a second moment arm. Positioned axially rearward of the Power supply 214, is the computer interface 216, that transmits information to the computer unit 64.

As also illustrated by FIG. 5, the device 250 has an outer housing body 218 which can include an internal antenna 220. In an alternative embodiment, the outer housing body 218 is connected to a pen cap 230 which also has an antenna 221.

FIG. 6 illustrates in more detail the construction of the movement sensor 204 and the tilt sensor 212. Both the sensor 204 and the tilt sensor 212 can have the identical construction. For clarity, the following description is made with reference to the sensor 204. In the embodiment shown eight pairs of transducer elements 206 are mounted along the outer face of the sensor 204. Each pair of transducers 206 is mounted proximate to one of the eight figure-eight shaped slots 260 that extend through the sensor 204. The transducers 206 are separated from the widest portion of the figure-eight grooves, by a 3 mils thick wall, Each figure-eight shaped slot is positioned proximate to one of four rectangular shaped 26 that extend through the sensor 204. The widest portion of the figure-eight slots 260 is separated for the grooves 262 by the same wall thickness that separates the transducers 206 from the figure-eight 260.

There are four connection mounts 258, located along the inner surface 256 of sensor 204. The mounts 258 hold the cylindrical seat 202 within the sensor. The illustrated sensor 204 has a collar 254 that encircles the outer surface of the sensor 204.

With reference to FIGs. 6 and 7, it can be seen that between any two mounts 258, are two pairs of transducers 206 and two figure-eight shape slots 260. Forces applied to the stylus 200, are radially transmitted by the mounts 258, to a point on the inner surface 256 between two figure-eight slots. Each figure-eight slot 260 distorts and each pair of transducers 206 measures the distortion. As shown in FIG. 7, each pair of transducers 206 is also positioned radially across from a second pair of transducers 206. The transducers 206 are then spaced along the outer surface to divide the outer surface of the sensor 204 along two orthogonal axes 264 and 268. As further illustrated by FIG. 7, each pair of transducers 206 is electrically coupled to a second pair of transducers 206, to form a sensing circuit 270 around the ends of the axes 264 and 268, and between two connection mounts 258 for clarity, only one of the four circuits 270 has been shown. In the embodiment shown, the circuit 270 is constructed as a Wheatstone bridge. Other circuit topologies, generally known in the art of strain sensor construction, such as half-Wheatstone bridges, can be readily substituted.

FIGs. 8A and 8B illustrate a further alternative sensor construction. FIG. 8A depicts a sensor 350 that includes a substrate 352, cutouts 354, 356, 358 and 360, an optional center aperture 362, transducers 364, circuit elements 368, temperature compensation element 370, bonding pads 372, and transverse axes 380 and 382.

The sensor 350 depicted in FIGS. 8A and 8B is a semi-conductor device that provides in a unitary and easily manufactured package, a sensor that measures forces applied to the central portion of the sensor 350. As depicted by FIG. 8A, the sensor 350 is formed from a substrate 352 that has a plurality of cutouts that are evenly distributed about the interior periphery of the substrate 352. In the depicted embodiment of 8A, the cutouts 354 - 360 are depicted as curved apertures that extend completely through the substrate creating an opening that extends between an upper and a lower surface of the substrate 352. The apertures 354 - 360 allow the central portion of the substrate 352 to move responsive to an applied force. Accordingly, the central portion of the substrate 452 becomes a deflecting portion of the sensor 350. As further depicted by FIG. 8A, the deflecting portion of the substrate 352 connects to a peripheral portion of the substrate 352 by four arms that extend along the transverse axes 380 and 382. In the depicted embodiment, the arms of the sensor 350 are formed by the portions of the substrate 3 52 that extend between the periphery of the substrate 352 and the deflecting portion of the substrate 352 and which run between the cutouts 354 - 360. For example, FIG. 8A depicts one arm as the portion of the substrate 352 that extends from the periphery of the substrate 352 to the central deflecting portion, and that runs between the cutouts 354 and 360 and extend along the axis 382. In this depicted embodiment, the peripheral portion of the substrate 352 can be fixedly mounted, for example, to the housing of a pen, and the central deflecting portion is disposed free to deflect responsive to an applied force. The deflections can train the arms that can be fixedly mounted at the periphery of substrate 352, thereby providing strains and stresses that can be measured for generating signals representative of the force applied to the deflecting portion of the sensor 350. Accordingly, the sensor 350 provides and easily manufactured semi-conductor device suitable for acting as a sensor for measuring forces, such as the forces applied to the tip of stylus as it traces written information on a writing surface. As described above, the depicted sensor 350 can act as a movement sensing the contact sensing elements, by measuring forces in three directions.

FIGs. 8A and 8B depict a substrate 352 that is formed on silicon and can be formed from a silicon wafer that has been processed to include bulk and thin film electronic devices. For example, the silicon wafer can be processed to include bulk devices such as resistors that can act as strain gauges for the sensor 350. Further, the substrate 352 can include CMOS thin film electronic devices, such as operational amplifiers and diodes that form the Wheatstone bridge and amplifier circuitry, as described above, that configure the transducer element as a circuitry, as described above and in EPO 649 549 B1, that configure the transducer elements as a circuit suitable for measuring applied forces. Similarly, the substrate 352 can include wiring that interconnects the electronic elements and that further connects the electronic elements to the depicted bonding ads 72 that can form contacts to exterior circuitry including, a power supply and an analog to digital converter board that can convert the force signals generated by the sensor 350 into digital signals.

FIG. 8A depicts cutouts 354 - 360 that are arced apertures that extend through the substrate 352. The depicted cutouts 354 - 360 provide apertures through the substrate 352 that disconnect the central portion of the substrate 352 from most of the peripheral portion of the substrate 352, leaving the central portion of the substrate 352 to be supported by four arms that tend relative to the axes 380 and 382. In this way, the cutouts 354 - 360 provide within the substrate 352 a deflecting portion and a plurality of arms that support the deflecting portion. The depicted cutouts -354 - 360 extend all the wav through the substrate body 352. However, in alternative embodiments, the cutouts can extend partway through the substrate 352 and still provide a central deflecting portion supported by a plurality of arms. Moreover, the cutouts 354 360, in an alternative embodiment, can be large apertures that remove from the substrate 352 entire portions of the substrate body. FIG. 8A depicts a preferred embodiment of the invention that provides long

thin apertures that extend all the way through the substrate body 352 and still provide sufficient surface area for the substrate 352 to carry electronic devices thereon. Moreover, the arced cutouts 354 - 360 isolate the electronic devices 368 and 370 from the distortions that effect the transducer elements 364, and which could effect the operation of the circuit elements 368 and 370. Although FIG. 8 depicts one embodiment of the invention, it will be apparent to those of ordinary skill in the art of micro-machine manufacture that any cutout, or cutout geometry that provides a deflecting portion for the sensor 350, can be practiced with the invention.

The depicted optional cutout 362 is a central aperture that provides a mechanical connection to a stylus element, or to a mechanical assembly that connects to a stylus element.

The depicted transducers 364 of FIG. 8A are shown as bulk resistors that act as strain gauges for measuring the strains occurring on each arm responsive to the deflection of the central deflecting portion of the substrate 352. In one embodiment of the invention, the strain gauge transducers 364 are bulk resistors formed on the substrate 352 surface during a semiconductor processing operation of the type commonly used for forming such resistors. Although the depicted transducer elements 364 are shown as strain gauges, it will be apparent to those of ordinarily skill in the art that other transducer elements suitable for generating signals representative of the deflection of a central deflecting portion can be practiced with the present invention.

The circuit elements 363 depicted in FIG. 8A typicallly include wire elements that are preferably formed on the substrate 352 during a semi-conductor processing operation, and that are reconnected together to the transducer elements 364, to form a full or half Vheatstone bridge. The circuit element 363 can further include operational amplifier circuitry for processing and amplifying the signals generated by the Wheatstone bridge to provide signals representative of the forces applied to the deflecting, portions of the sensor 350. The design and construction of such circuitry is well known in the art of electrical engineering and any circuitry suitable for processing and amplifying signals generated by a Wheatstone Bridge can be practiced with the invention.

As further depicted in FIG. 8A, the circuit element 370 can be included, which includes a temperature compensation circuitry that compensates for the effects of temperature changes on the measurement of the applied forces. In particular, the temperature compensation circuitry 370 can compensate for thermal expansion that can occur as a result of the substrate 352, or transducers 364 rising in temperature. The depicted circuitry 370 can be formed of thin film and bulk devices formed on the substrate 352 during a semi-conductor manufacturing process. Typically, these devices include diodes which are temperature sensitive. Such a construction provides for improved performance and reduced variations and device characteristics. FIG. 8A further depicts a preferred embodiment of the sensor 350 that has a circular geometry which provides for a more uniform thermal expansion which is more readily compensated for by the circuitry 370 and which is less disruptive of the signals generated by the transducers 364.

FIGs. 9A and 9B depict further alternative embodiments of the invention that include a sensor suitable for measuring forces applied to the tip of a stylus. FIG. 9A depicts a sensor 390 that has a substrate 3 92, cutouts 394, 396 and 398, a central aperture 400, contact points 404, and strain gauges 406. FIG. 9B depicts that the substrate 392, which can be a metallic material, such as steel, can also include a surface coating 408 which can be a ceramic material such as aluminum oxide (AlO_2).

FIG. 9A illustrates an alternative geometry for forming a deflecting portion within the surface of a substrate 3 92. In the depicted embodiment, a plurality of angular cutouts are formed as apertures extending through the body of the substrate 392. Three arms are formed that extend between the cutouts and that connect the central deflecting portion to the peripheral portion of he sensor 390. As depicted in FIG. 9A, the three arms have attached thereon transducer elements 406 which, as described above, can be strain gauge elements measuring the strain caused by deflections of the central deflecting portion of the sensor 390. In this embodiment, the forces measured by the three arms can be resolved into component forces acting relative to an orthogonal set of axes. In one practice, one side of one cutout is defined as running along the x-axis of a coordinate system. The other cutouts, which run transverse to the x-axis can be resolved into portions that run parallel to the x-axis and normal thereto. Accordingly, forces can be measured relative to an orthogonal pair of axes. Further, alternative systems can be used for measuring and resolving forces acting on the deflecting portion of the sensor 390. These systems are well known in the art of sensor design and any such systems suitable for measuring the forces acting on the deflection portion of the sensor 390 can be practiced with the invention.

As depicted in FIG. 9B, the steel substrate 392 can include an aluminum oxide or other ceramic film surface 408. Contact pads 404 can be formed on the ceramic surface and wire elements can run between the transducers 406 and the contact pads 404 to interconnect the transducer elements with the contact pads 404. In one embodiment of the invention, the contact pads 404 form pin connections for connecting to a semi-conductor device that can be soldered, surface mounted, or otherwise attached to the contact pads 404. As will be readily recognized by one of ordinary skill in the art of electrical engineering, the semi-conductor device attached to the contact pads 404 can be a circuit for detecting strains measured by the transducers 406 and generating, responsive to the measured strains, signals representative of the forces acting on the deflecting portion of the sensor 390.

Figure 10 shows the integration of sensors of the

invention into a stylus as described above. FIG. 10 depicts a system 410 that includes a sensor 414 of the type depicted in FIGS. 8A, 8B, 9A, and 9B. In particular, FIG. 10 depicts a system 410 that includes a housing 412, a sensor 414, a support 418, a contact 420, support 422, support 424, container 428 and stylus 430.

As depicted in FIG. 10, the system 410 mounts the sensor 414 so that the peripheral portion of the sensor 414 is fixably mounted by supports 422 and 424 to the housing 412 of the system 410. Typically, the housing 412 can be the exterior portion of a pen device that is used for imaging written information. As further depicted in FIG. 10, the sensor 414 can have contact elements 420 that are electrically conductive contact elements for forming a circuit connection to a contact point provided on support 422. In this way, the sensor 414 can couple electrically through the contact 420 and support 422 to an external power supply processing element, or other electronic circuitry.

As further depicted by FIG. 10, a container 428 extends through the central aperture of the sensor 414 and sits proximate a support wall 418. The support with 418 is fixedly mounted against supports 424 and is selectably flexible. The support wall 418, therefore, acts as a mechanical stop and controls the amount and distance that the container 418 can distort the deflecting portion of the sensor 414. In one embodiment, support wall 418 is formed from a thin piece of aluminum.

As further depicted in FIG. 10, stylus element 430 which can be any available pen stylus, or cartridge, is seated within the container 428 that extends through the deflecting portion of the sensor 414. As it will be understood as the stylus elemem 430 traces across the writing surface,. the forces applied to the tip of the stylus 430 act upon the sensor 413 which generates signals representative of these forces.

FIG. 11 depicts a further alternative embodiment of the invention that includes a sensor such as those depicted in FIGS. 8A, 8B, 9A, and 9B. FIG. 11 depicts a system 440 that includes a sensor 442, a flexible circuit board assembly 444, a battery element 448, and contact pads 450. In the embodiment depicted in FIG. 11, the sensor element 442 electrically connects via the contact pads 450 to a flexible circuit board assembly 444 that is formed into a cylinder. The battery 448 is disposed within the cylindrical flexible circuit board assembly 444 and can provide power to the sensor 442 that, as depicted is also formed into a circle. A stylus element, not shown, can extend into the cylindrical circuit at the end opposite the battery 448 and can contact, as described above, against the circuit 442 for distorting a central portion thereof In this embodiment, the system 440 can be inserted into the circular housing of a pen device to thereby provide a sensor assembly that includes the sensor element 442 and a flexible circuit board 444 which is a circuit assembly for detecting and measuring forces sensed by the sensor 442. Accordingly, the system 440 provides a sensor assembly that can be inserted into the housing of a pen device to provide an instrument suitable for imaging written information.

The depicted sensors can be formed by a repeatable manufacturing process that provides sensors having semi-conductor features to provide thereby improved tolerance and uniform performance. In one process according to the invention, a silicon wafer is processed, according o conventional semi-conductor processing techniques, to form thereon a plurality of semiconductor devices, each of which can include the electronic assemblies of a sensor, such as the sensor depicted in FIG. 8. In other words, semi-conductor processes can be employed to form the transducer elements, circuit elements, wiring patterns, and other such semi-conductor features. On a single silicon wafer, a plurality of such devices are formed. The process wafer is passed to a milling station that cuts the silicon wafer into a plurality of separate sensor devices.

In one embodiment, the milling station directs a laser beam at the silicon wafer and cuts from the wafer individual sensors that have a select geometry. For example, as depicted in FIG. 8A, the laser can cut each sensor to have a circular geometry, or any select geometry that is suitable for packaging the sensor within the housing of a pen device. For example, alternative geometrys, such as rectangles, ovals, hexagons, or any geometry can be achieved by milling the wafer. As mentioned above, the milling station can employ a laser beam to cut the sensor elements from the silicon wafer or, alternatively, can employ a focused ion beam device to cut the individual sensors from the silicon wafer.

In alternative processes, a metallic plate, such as steel, is coated with a ceramic material and semi-conductor processes are employed for forming on the ceramic coating a set of semiconductor devices, such as bulk resistors, or other such tick film devices. As described above, the metallic plate can be milled, either mechanically or using the ablating techniques of a laser beam, ion beam, or other such ablating technique to cut individual sensor devices from the plate being milled.

The sensors depicted in FIGS. 8 and 9 can also provide semi-conductor devices suitable for measuring forces in three directions. As depicted in FIGS. 8 and 9, the semi-conductor sensors are illustrated as providing movement sensing elements and contact sensing elements. in alternative embodiment, three of such sensors can be employed for providing a tilt sensor suitable for use with the systems disclosed herein. In particular, with reference again to FIG. 8, three sensor elements, such as the depicted sensor element 350 can be orthogonally disposed to measure forces working along three orthogonal directions. Each sensor 350 is provided with a metallic core, preferably a soft metal core, within the central aperture 362. By providing an alternating current to the core, mechanical vibrations can be set up within the metallic core, much like a tuning fork. As is known in the art of accelerometers, the conservation of angular momentum provides that as the sensor 350 moves, the vi-

brating metal core will resist movement causing stresses and strains to be measured by the transducers 362. By measuring the stresses and the strains, the angle of the pen can be determined and measured independent of the action of the gravitational field. In one embodiment of this accelerometer, as the forces generated by the metallic core are quite slight, the thickness ofthe substrate 352 is reduced by ablation. Optionally, the rear surface of the sensor 350 is ablated to reduce the thickness of the substrate 352 to a thickness that provides for maximum sensitivity and yet yields sufficient robustness to prevent the sensor 350 from being easily damaged by the vibrating metallic core.

It should be understood that the above description pertains to but a few of the several electronic imaging systems of the invention and the description is intended as illustrative rather than limiting. The invention, therefore, is to be defined not by the preceding description but by the claims that follow.

Claims

1. Apparatus for measuring an applied force, comprising a substrate having

    an upper surface, a lower surface and a peripheral portion, and
    a plurality of cutouts disposed between said upper and lower surfaces and spaced inwardly from said peripheral portion to form a deflecting portion disposed inwardly from said cutouts, and to form a plurality of arms that connect between said deflecting portion and said peripheral portion.

2. Apparatus according to claim 1 wherein said plurality of cutouts includes four cutouts and said plurality of arms includes four arms.

3. Apparatus according to claim 2 wherein said arms extend radially outward from said deflecting portion and along a set of transverse axes.

4. Apparatus according to claim 1 wherein said plurality of cutouts includes three cutouts and said plurality of arms includes three arms.

5. Apparatus according to claim 1 further comprising,

    transducers mcunted to said plurality of arms to generate deflection signals representative of a deflection of said deflecting portion responsive to said applied force acting on said deflecting portion.

6. Apparatus according to claim 5, wherein said transducers include a strain gauge.

7. Apparatus according to claim 1 further comprising

    a circuit electrically connected to said transducers for generating, responsive to said deflection signal, a force signal representative of said applied force.

8. Apparatus according to claim 6, further comprising

    a temperature compensator for detecting a temperature characteristic and coupled to said circuit for directing said circuit to generate said force signal responsive to said temperature characteristic.

9. Apparatus according to claim 7, further comprising

    bonding pads disposed on said substrate and electrically coupled to said circuit.

10. Apparatus according to claim 9 wherein said bonding pads are disposed along said peripheral portion of said substrate.

11. Apparatus according to claim 1 wherein said substrate comprises a silicon substrate.

12. Apparatus according to claim 1 wherein said substrate comprises a metallic substrate.

13. Apparatus according to claim 12 further comprising an aluminum oxide coating disposed on one of said upper and lower surfaces.

14. Apparatus according to claim 1 wherein said substrate comprises a substantially circular substrate.

15. Apparatus according to claim 1 wherein said substrate further comprises a centrally located aperture.

16. Processes for manufacturing a sensor for measuring an applied force, comprising the steps of

    providing a substrate body having a peripheral portion., an upper surface and a lower surface, and
    forming within said substrate body a plurality of cutouts that extend between said upper and lower surfaces and that are spaced inwardly from said peripheral portion to form a deflecting portion and a plurality of arms that connect between said deflecting portion to said peripheral portion.

17. Processes according to claim 16 wherein said step of providing said substrate body includes the step of milling a silicon wafer.

18. Processes according to claim 17 wherein said step of milling includes the step of directing a laser beam at said silicon wafer.

19. Processes according to claim 17 wherein said step of milling includes the step of directing an ion beam at said silicon wafer.

20. Processes according to claim 17 including the further step of milling said silicon wafer to form said peripheral portion in a select pattem.

21. Processes according claim 16 including the further step of

    forming a bulk device on one of said surfaces of said substrate.

22. Processes according to claim 16 including the further step of forming a thin film semiconductor device on said substrate.

23. Apparatus for imaging writing, comprising

    a stylus,
    a sensor that couples to said stylus and includes a plurality of cutouts for forming a deflecting portion, and a plurality of arms,
    transducers mounted to said plurality of arms for venerating deflection signals representative of a deflecting motion of said deflecting portion, and
    a circuit for generating responsive to said deflection signals, force signals representative of a force acting of said stylus.

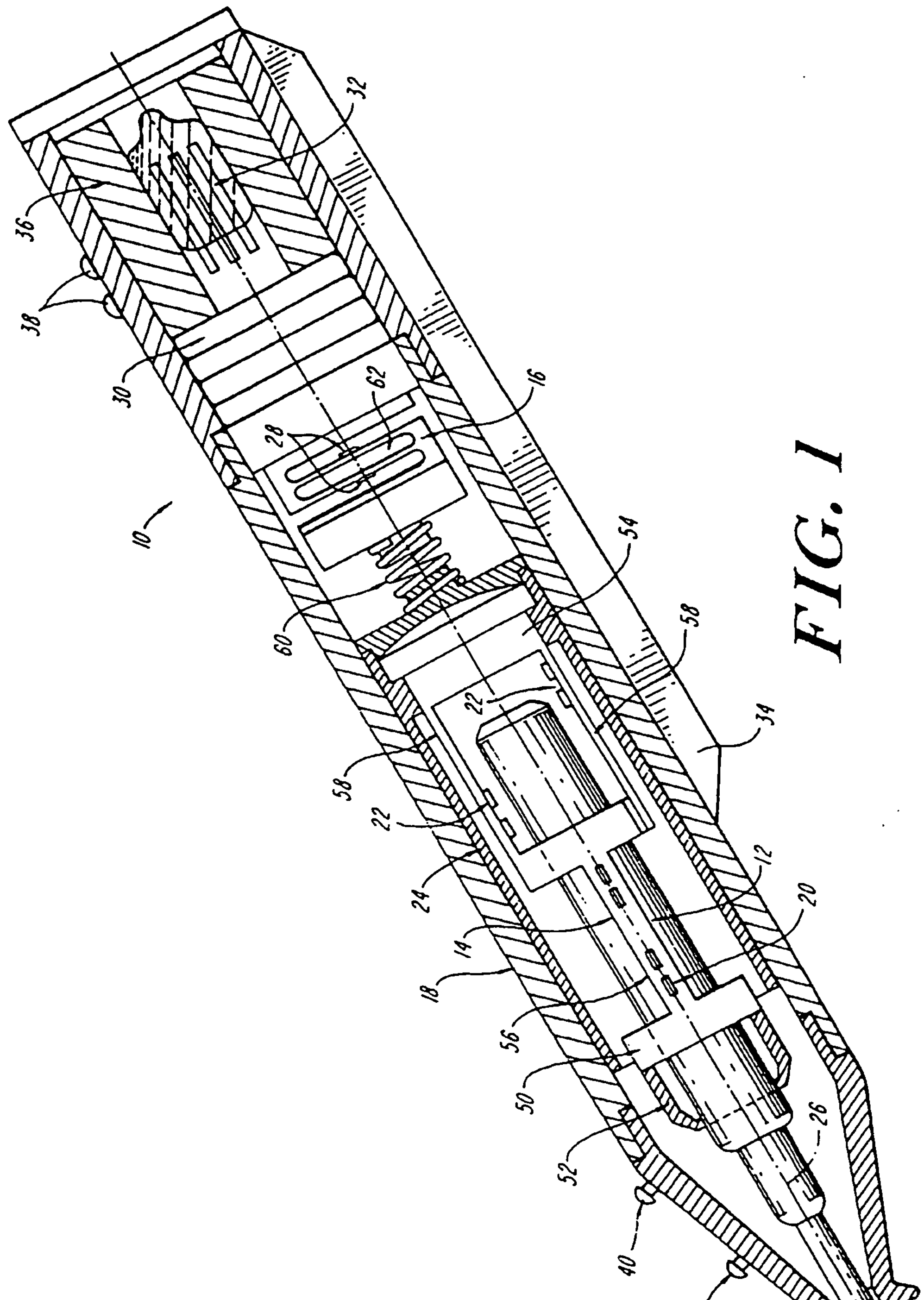
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FIG. 1

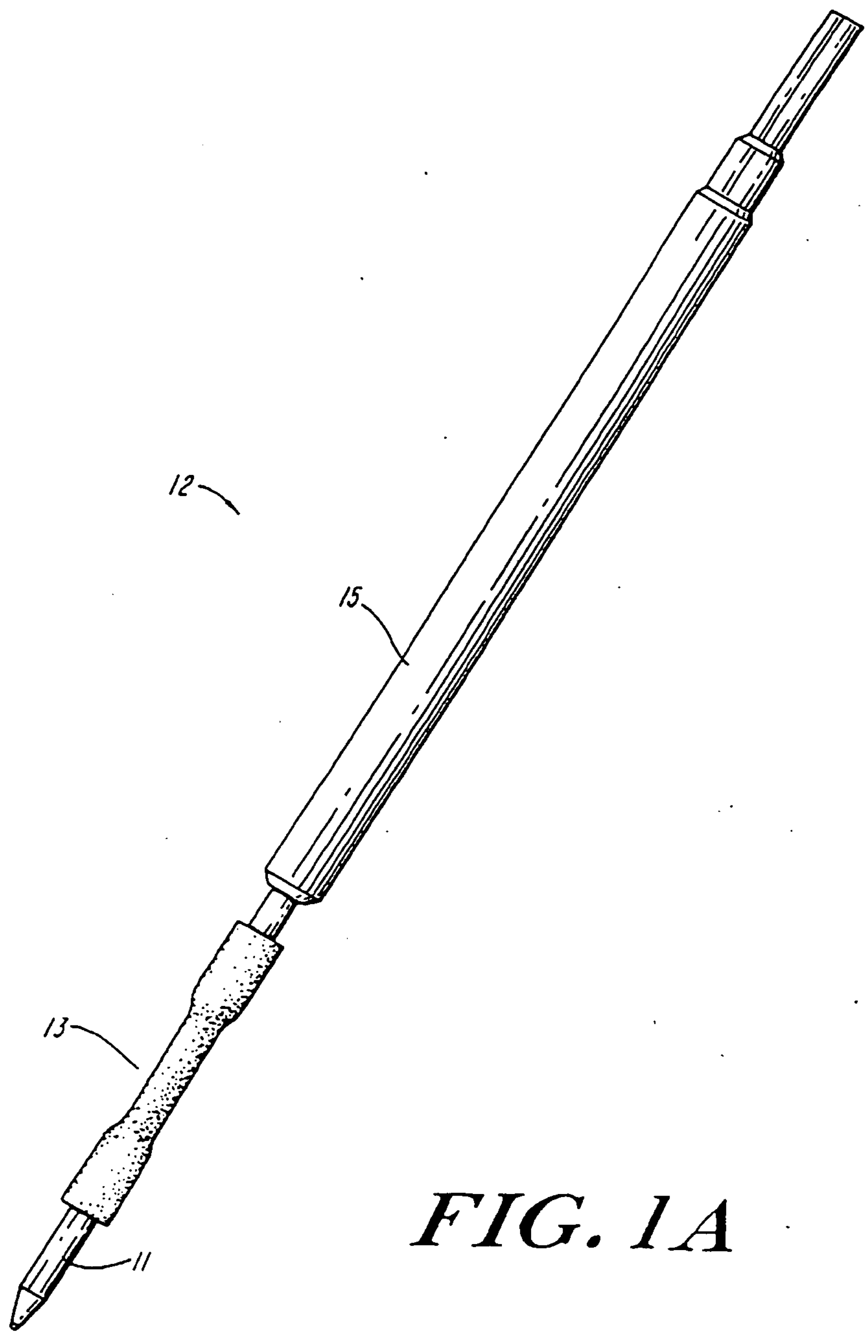

FIG. 1A

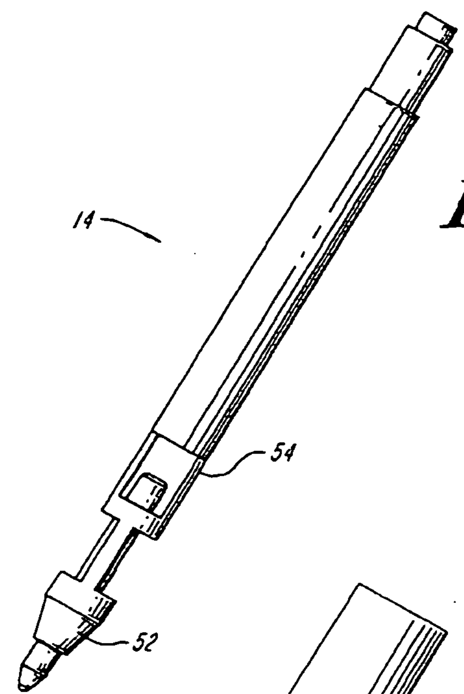

FIG. 1B

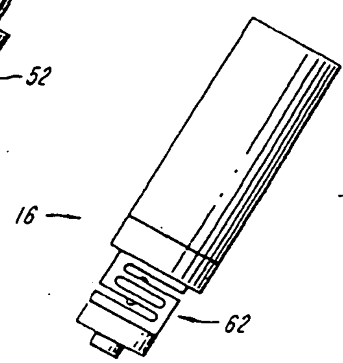

FIG. 1C

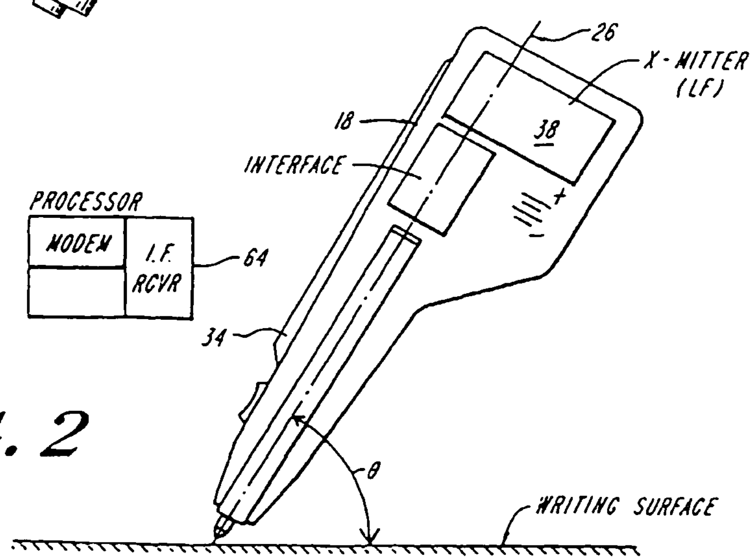

FIG. 2

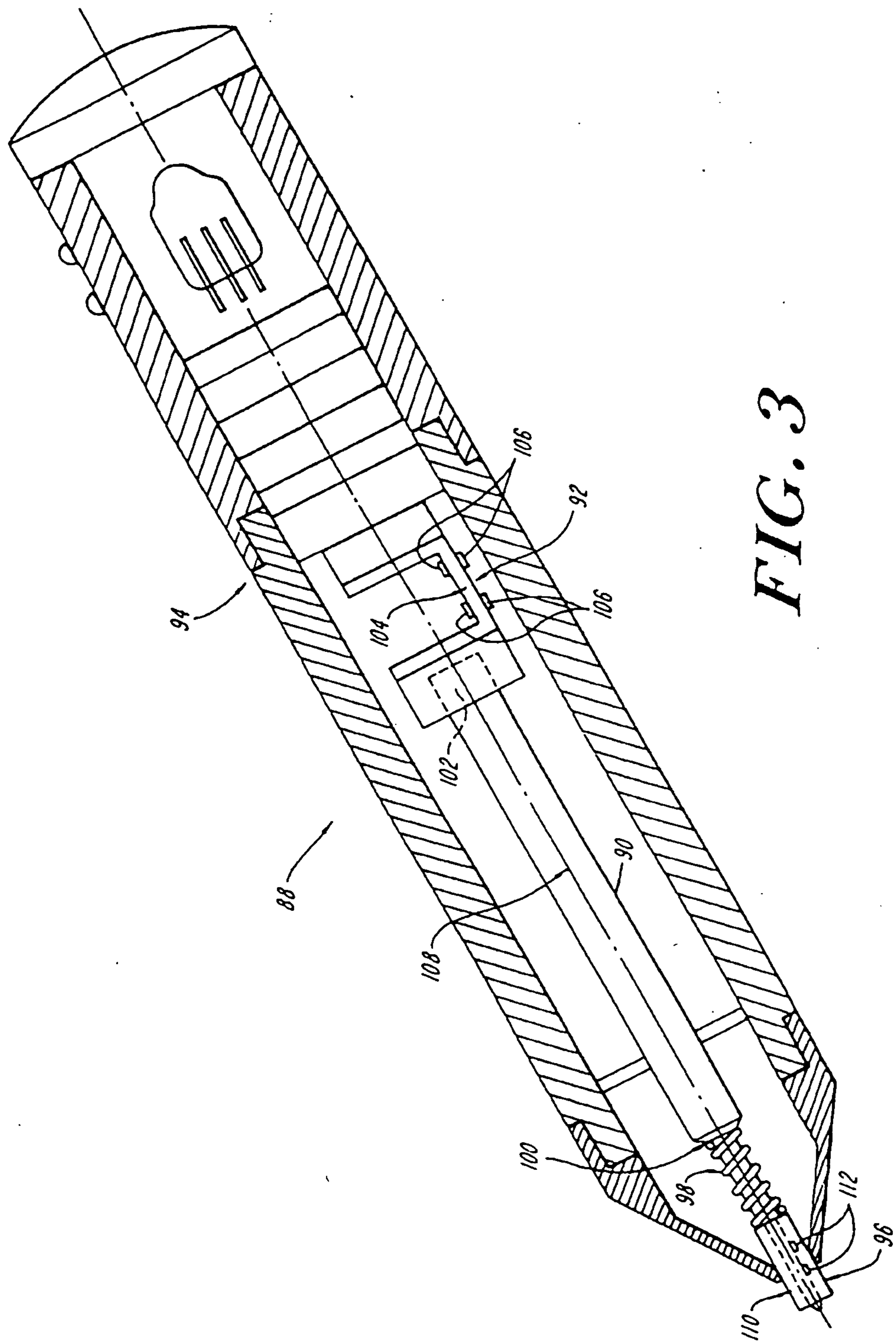

FIG. 3

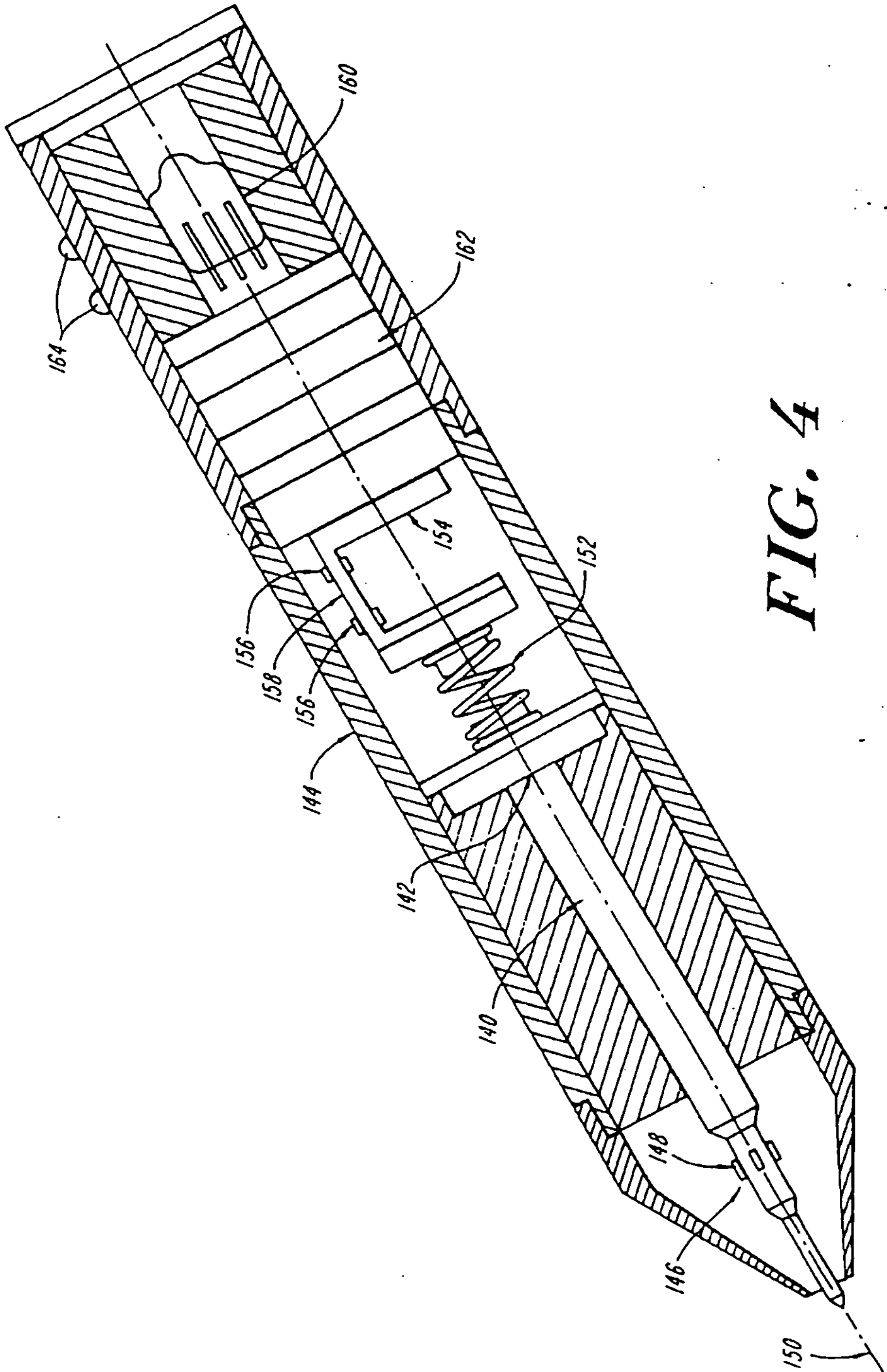

FIG. 4

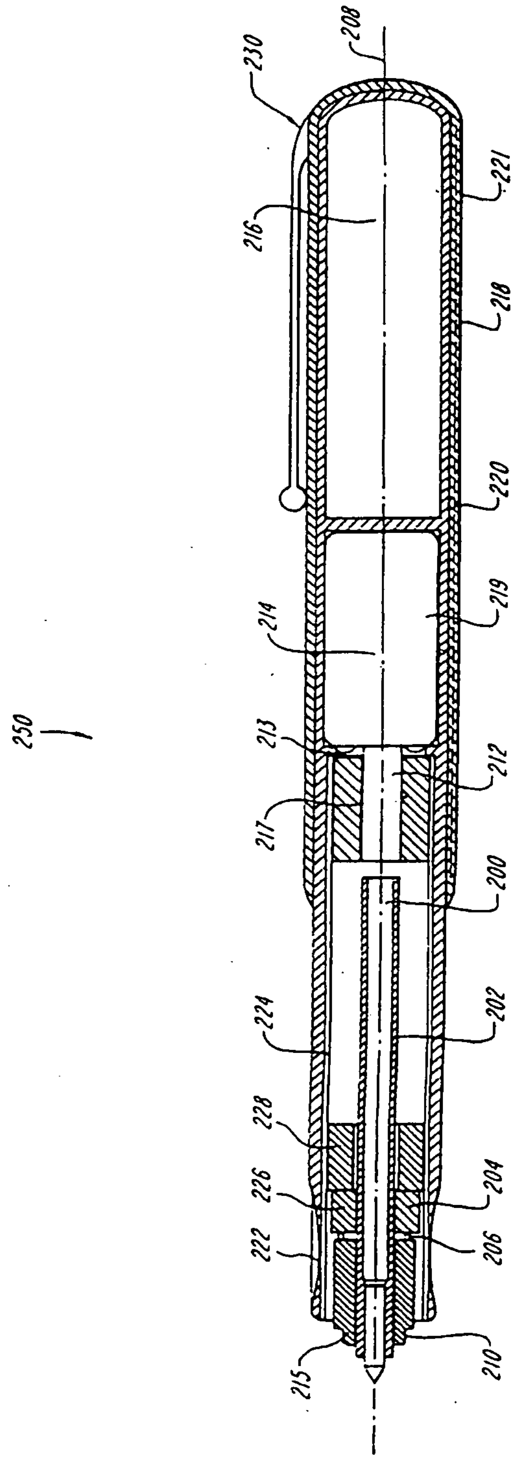
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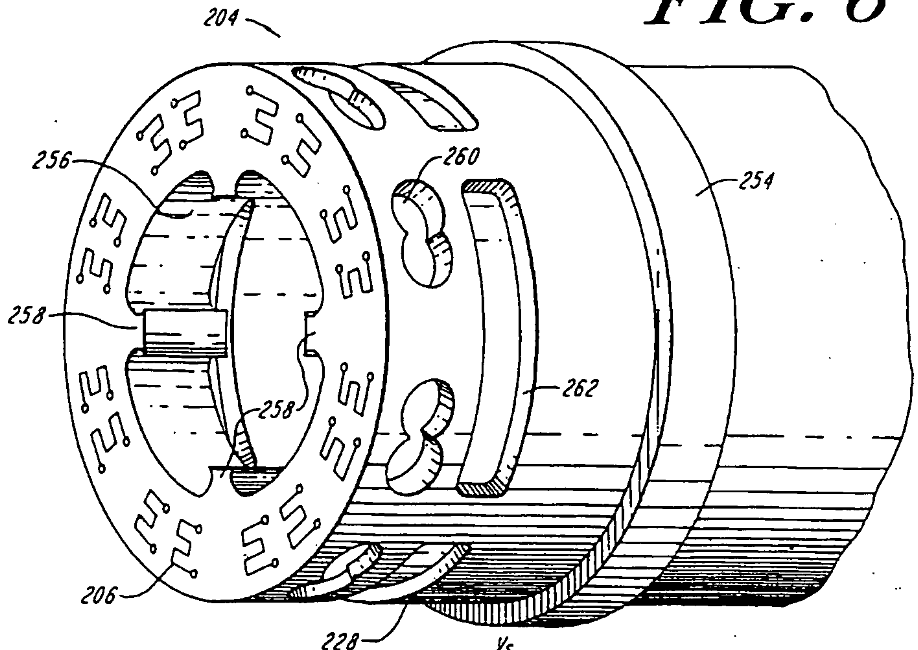
FIG. 5

FIG. 6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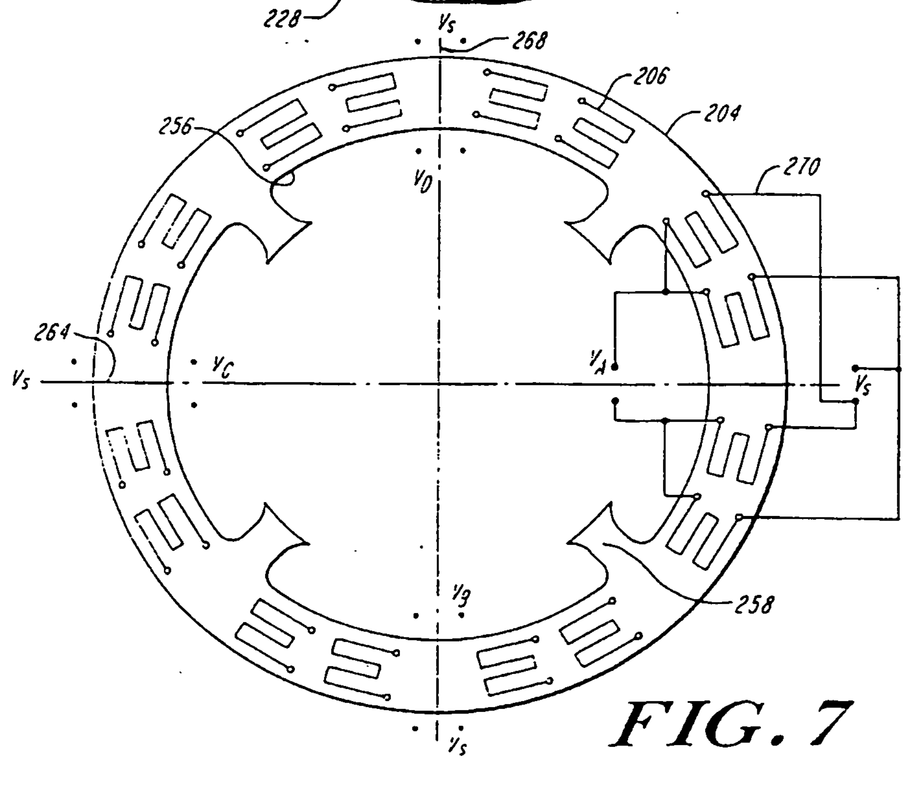
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FIG. 7

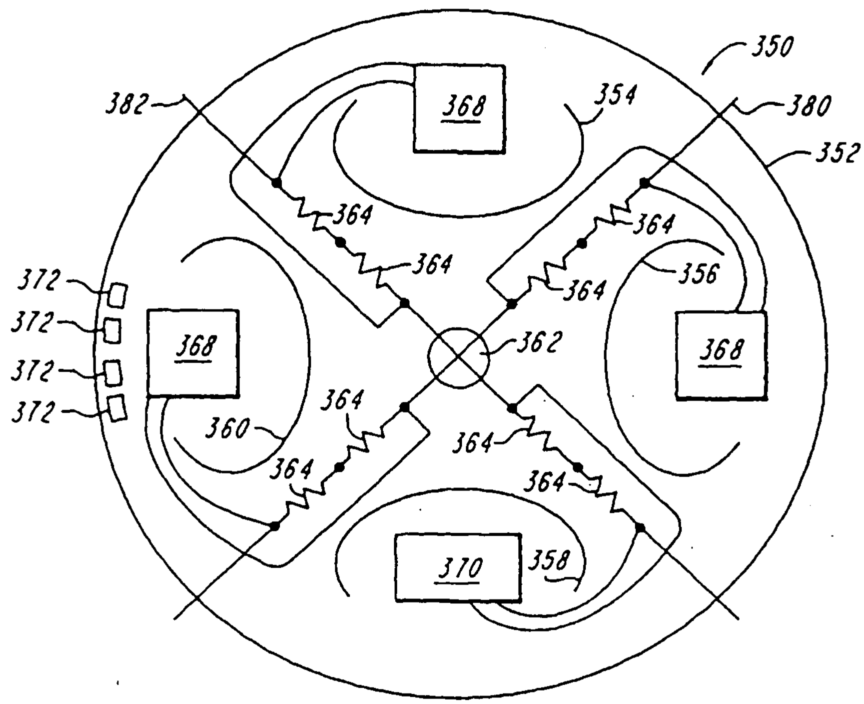
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FIG. 8A

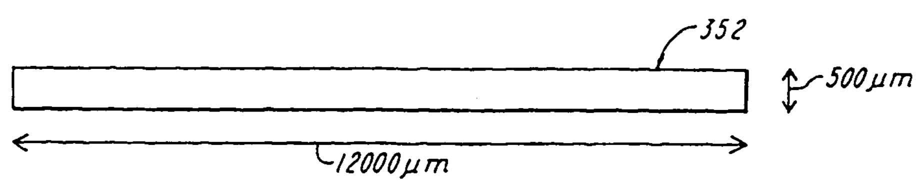
352
500μm
12000μm

FIG. 8B

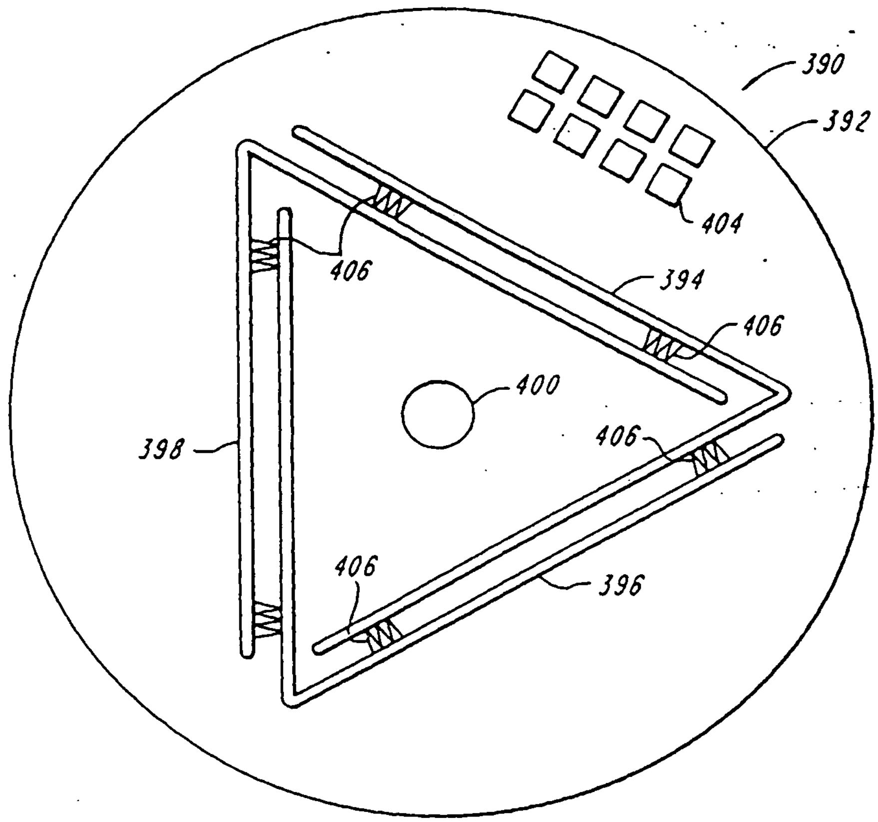

FIG. 9A

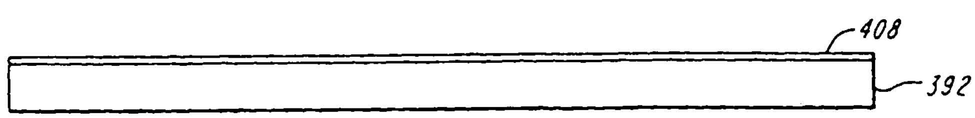

FIG. 9B

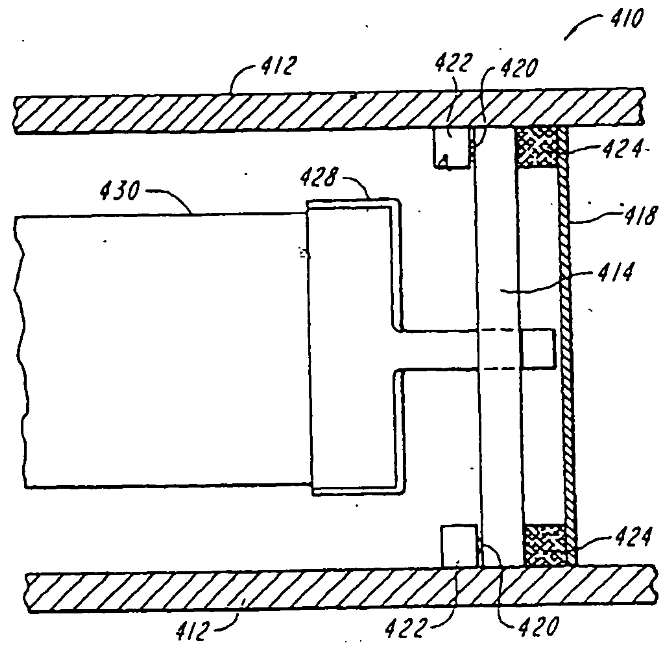
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FIG. 10

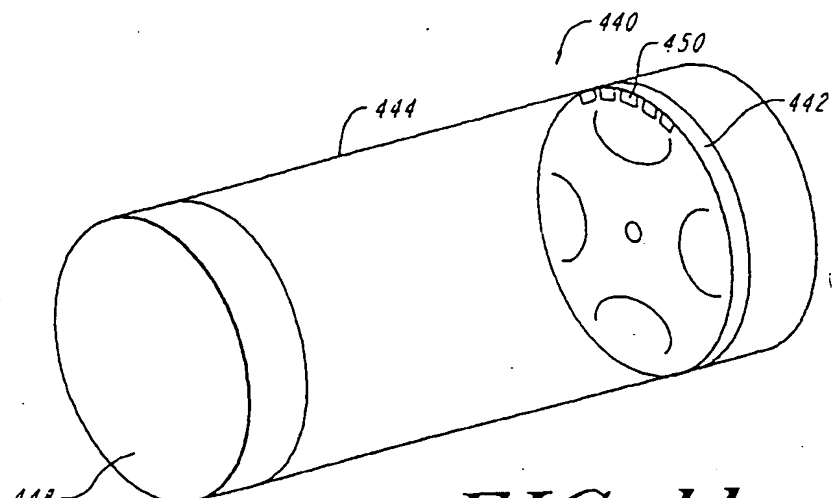
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FIG. 11

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 97 30 6257

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X	US 4 116 075 A (ORT WERNER)	1-3, 5-11,14, 15	G06K11/18 G01L5/16
	* column 2, line 47 - line 62 * * column 4, line 30 - column 5, line 9; figures 6,7 *		
Y		4,23	
Y	US 4 896 543 A (GULLMAN LARRY S) * column 2, line 34 - column 3, line 25; figures 1-3 *	4,23	
A	US 3 915 015 A (CRANE HEWITT D ET AL) * the whole document *	1-23	
A	US 4 751 741 A (MOCHINAGA NOBUYUKI ET AL) * column 3, line 2 - line 14 * * column 3, line 28 - line 52 * * column 16, line 20 - line 44; figures 2,20 *	1-23	
D,A	WO 94 01834 A (SMART PEN INC) * the whole document *	1-23	TECHNICAL FIELDS SEARCHED (Int.Cl.6): G01L G06K

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	17 February 1998	Nygren, P

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
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P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons
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